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A SIMPLE FAST SWEEPING SYSTEM FOR EXTRACTED CYCLOTRON BEAMS

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A simple system for sweeping an extracted cyclotron beam on and off an adjustable aperture at various repetition rates and duty cycles is described. This system permits lifetime measurements of delayed γ-rays to be made over a range of 0.5 to 5000 μs. The application of this system for the study of the 3.29 and 159 μs isomeric states in ^{115}Sn populated by the (p, nγ) reaction at 8.0 MeV is described.

Of considerable interest in nuclear spectroscopic investigations is the determination of the lifetimes of delayed γ-rays emitted in nuclear reactions. For lifetime measurements in the approximate range of 0.5 to 5000 μs rapid-beam-deflection techniques have been employed. Pulsing of the internal beam of the cyclotron at Michigan State University (MSU) was reported by Johnson et al.[1]) who stopped the beam on a collimator on the first one-half turn by applying a dc voltage to a radially deflecting plate located in the dee between the ion source and collimator. In order to increase the available time range an rf beam sweeper which pulses a pair of electrostatic deflecting plates in the MSU cyclotron and thus deflects the extracted beam, was also reported[2]). Other external beam deflection systems have been reported by Abrahamsson et al.[3]) at Stockholm and Fauska et al.[4]) at Seattle. In addition beam deflection has also been accomplished by pulsing the cyclotron deflector voltage as reported by Rotter et al.[5]). However, many of these pulsing systems are unable to provide beam-on and beam-off periods over a wide time range[1–3]). In this paper a simple system for sweeping the extracted beam of the Washington University (St. Louis) cyclotron is presented which is suitable for life-time measurements over the wide range of 0.5 to 5000 μs. The characteristics of this system are described in conjunction with an application involving two isomeric states with widely different lifetimes.

A beam-sweeping system which deflects the beam on and off an adjustable aperture at various repetition rates and duty cycles has been assembled at the Washington University 137 cm cyclotron. The beam-deflecting electrode is located in the external beam tube just past the first focusing and steering magnets. The aperture is 2.5 m downstream, past the switching magnet at the object point of a set of focusing quadrupoles. The target station is some 5 m farther downstream past a 1.2 m thick concrete shielding wall. The beam is pre-collimated through a 6 mm diameter orifice in front of the deflecting electrode.

In practice the beam is focused on target and the aperture stepped down until it intercepts the edges of the beam. Then a 2 kV positive dc voltage is applied to the deflecting electrode, and the target current monitor is observed to verify that all the beam has been removed. Since upward deflection is employed, the upper aperture edge can be lowered farther until this condition is satisfied. Energizing the pulsing circuitry then "shorts" the deflecting electrode to ground at the preset repetition rate and duration interval. The system delivers beam bursts of 1 μs to 1 ms duration with duty cycles of less than or equal to 25%.

The deflecting electrode is supported by two glass-to-metal seals feeding through the wall of a 6.35 cm diam-

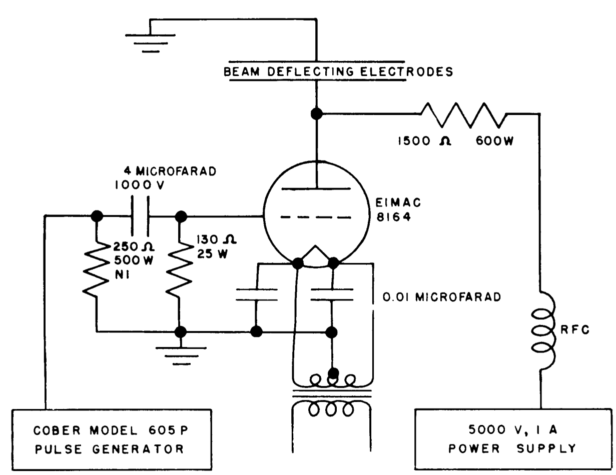

Fig. 1. Circuit diagram for pulsing the voltage of the deflecting electrode.

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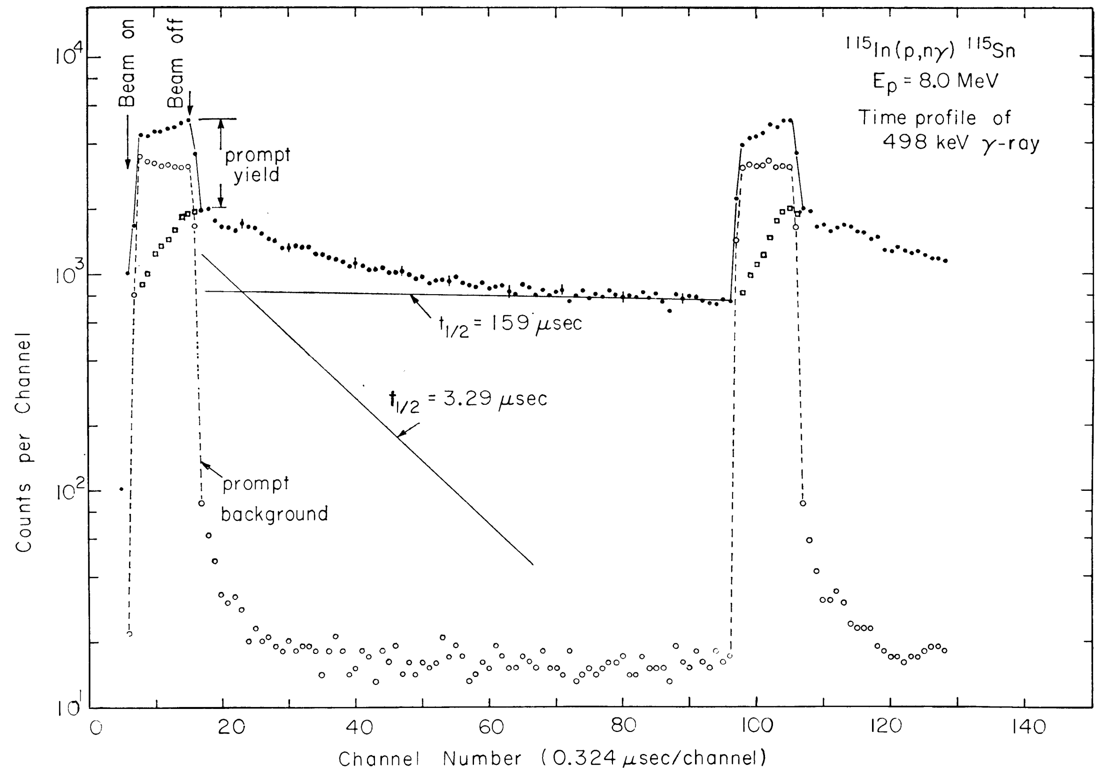

Fig. 2. Time profile (closed circles) of the 498 keV γ-ray de-exciting the 498 keV states in ^{115}Sn populated via the ^{115}In(p, nγ) reaction at 8.0 MeV. The open circles show the time profile of the prompt component for the 498 keV peak. The open squares show the growth of the delayed activity during the beam-on period. The decay curve of the delayed component was resolved into two 3.29 and 159 μs components.

eter beam line. This electrode is made of copper with dimensions 2.5 cm width, 50 cm length and 1.6 mm thickness. Parallel to it at 2.5 cm distance is an identical electrode at ground potential. Charged particles passing between the electrodes are deflected $5\,Q/E_{\mathrm{MeV}}$ cm/kV at 2.5 m distance from the center of the electrodes. This gives a deflection of 6.7 mm for 30 MeV α-particles with 2 kV deflecting voltage. Greater deflection sensitivity can be achieved by locating the aperture farther from the electrodes past the second set of focusing magnets, but with the disadvantage of undesirable background radiation from the aperture edge.

The pulsing system consists of a Cober Model 605P pulse generator driving an Eimac 8164 triode (fig. 1). These units are located directly below the deflecting electrodes to obtain close coupling. Grid leak bias keeps the tube cut off until a 400 V positive pulse causes it to conduct and "short" the deflecting electrodes. Operation of the 2200 V maximum Cober unit at 400 V pulse height allows an increase in maximum duty cycle from 1.5% to 25%. The 250 Ω resistive grid load helps optimize pulse shape. Voltage wave-forms on the deflector plates have rise and fall times of less than 200 ns. Timing signals are derived from the sync output of the Cober P27 plug-in unit, which can be synchronized with cyclotron dee frequency at high repetition rates.

In order to test this deflection system and demonstrate its properties we have investigated the 3.29 and 159 μs isomeric states in ^{115}Sn populated by the ^{115}In(p, nγ)^{115m}Sn reaction at 8.0 MeV proton bombardment energy. A natural indium foil (≈ 10 mg/cm^2) was employed as the target. A 35 cm^3 Ge(Li) γ-ray detector in an anti-Compton arrangement[6]) was used to record the prompt and delayed γ-rays. An Ortec model No. 437A time-to-amplitude converter (TAC) was used to measure time. The start pulse was derived from the sync output of the Cober P27 plug-in unit. The stop pulse was derived from a constant-fraction discriminator system triggered by the Ge(Li) detector preamplifier signal. An on-line PDP-8/L computer interfaced with a 4096-channel pulse-height analyzer was used to record the information. Preselected digital gates were placed on the γ-ray peaks and their corresponding

Compton backgrounds, above and below each peak, and the time spectra were recorded in a 128-channel resolution. An accurate calibration of the time axis was obtained by introducing known delays to the start signal and determining the shift of the leading edge of the prompt peak in the time spectrum. The rise and fall time at 1/10 height were determined from time spectra of prompt γ-rays taken at a resolution of 10 ns/channel and were found to be ≤ 200 ns.

The closed circles in fig. 2 show the time spectrum of the 498 keV γ-ray, which de-excites the 498 keV level[7]) in ^{115}Sn. This time spectrum exhibits a prompt and a delayed component which in turn can be resolved into two half-periods. A least-squares analysis of this decay curve gave (3.29 ± 0.10) μs for the short-lived component when the long-lived component was held constant at 159 μs. This is in good agreement with the value of (3.26 ± 0.08) μs obtained by Ivanov et al.[8]).

The open circles in fig. 2 show the time profile of the prompt component for the 498 keV peak. The open squares show the growth of the delayed activity during the bombardment and represent the difference between the closed and open circles. In this experiment the oscillators of the sweeper and the dee voltage were not synchronized.

When the 121 keV peak was examined it was found again to exhibit the same two components as the 498 keV peak, but it showed a considerably smaller prompt contribution. This is consistent with the $3/2^+$ assignment for the 498 keV state compared with the $7/2^+$ for the 3.29 μs 619 keV state, in view of the possible feeding of the 498 keV state from other low-spin higher lying states. Finally, the weaker 107 keV γ-ray was observed with only one component of 159 μs. This information is consistent with the decay scheme of Brinkmann et al.[7]) for these isomeric states.

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